# Extreme Temperature Design Techniques for a Venus Exploration S-band Transmitter

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# Outline

- Who are we
- What are we doing, how did we get into it
- Key problems
- Solutions
- Environmental tempering
- Working source list
- Preliminary system architecture
- Novel test chamber
- Summary

# Who Are We?

- Softronics Ltd. is a small business focusing on advanced radio technologies and product design for military and commercial applications
- Auburn University, Dr. R. Wayne Johnson, Director, Laboratory for Electronics Packaging and Assembly (high temperature die attach and bonding)
- Iowa Space Grant Consortium, Dr. William Byrd (test facilities, thermal analysis)

# What, How?

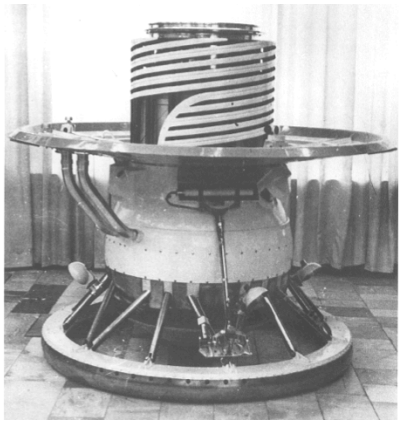
- Bid on NASA SBIR topic in 2004
  - Proposed an S-band telemetry transmitter that is mounted in *exterior ambient 465°C*
- Won a Phase I study award
  - Incinerated many objects in proving that we could really do that (transmit *and* incinerate…)
- Won a Phase II prototype award
  - Honing our techniques and trying not to incinerate as many objects….

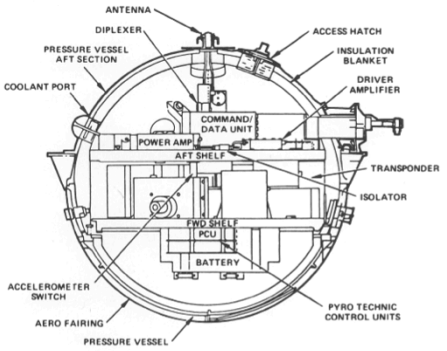
# Key Problems

- **Venusian ambient!!!**
  - 465°C temperature
  - 90 barr pressure
  - 97% $CO_2$
  - Sulfuric acid
    - Later advised that densities worst at altitude, minimal problem on ground, count on protective transit shroud

# The Solution

- Our innovation: exterior transmitter heatsunk to the ambient $CO_2$ atmosphere
- Objective: minimize mission size, weight by eliminating cooling for transmitter
  - Past efforts: cooled pressure vessel
- Key technologies:
  - Silicon Carbide transistors
  - "Olde Tyme Radios"





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High Frequency Radio System, Circuit & Software Solutions

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RESEARCH EXTENSION
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FOR THE ADVANCEMENT OF SCIENCE AND ARTS
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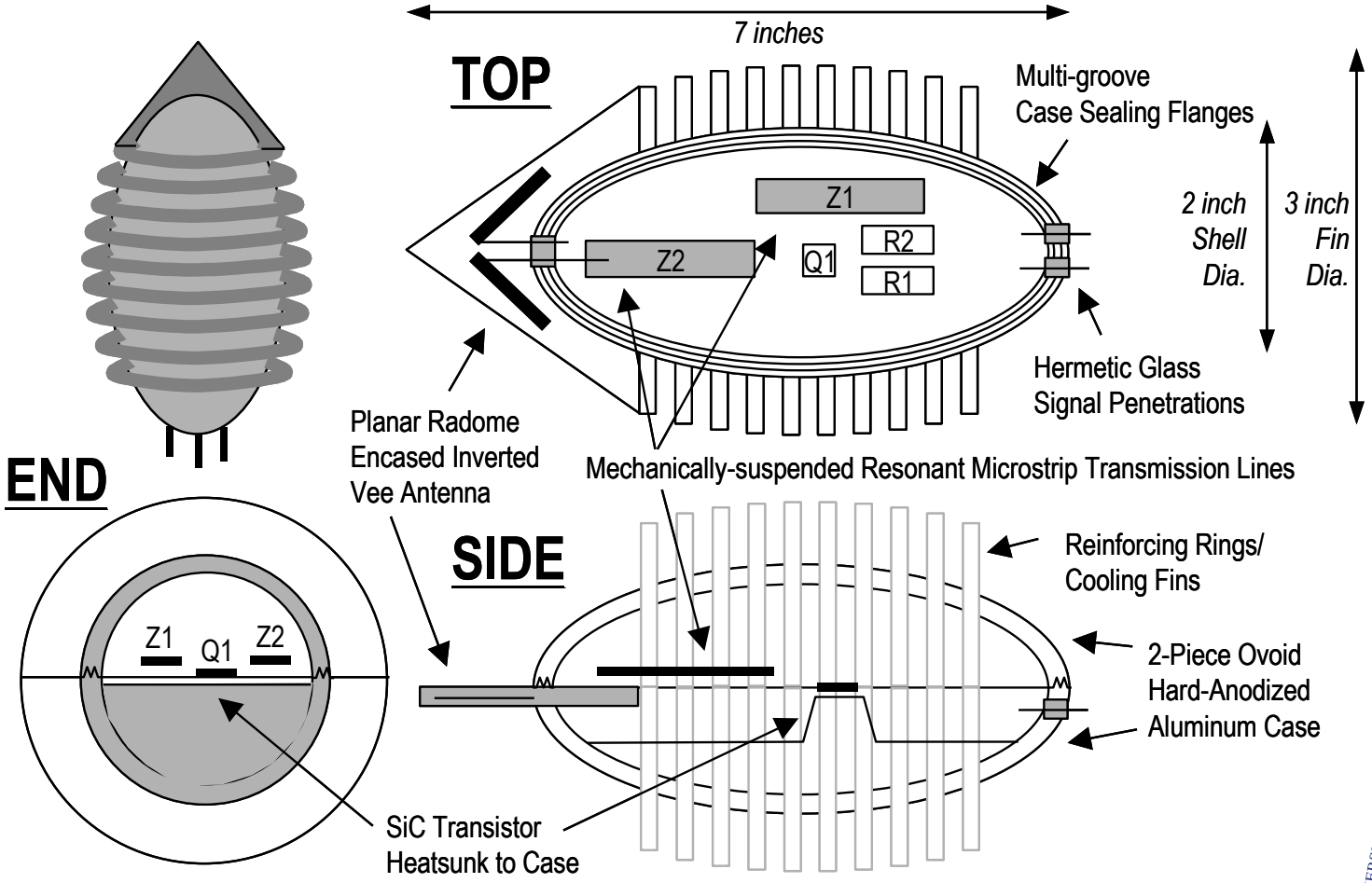
# Our Original Concept



# Environmental Tempering of Design

- No sulfuric acid to worry about
  - Do not need exotic acid-resistant case
- None of electronic components are pressure sensitive
  - Do not need pressure vessel
  - "Leaky gasket" sealed case to protect against particulates, GVS (green Venusian slime) but allow transit/landing equalization
- Components unaffected by $CO_2$

# The Solution

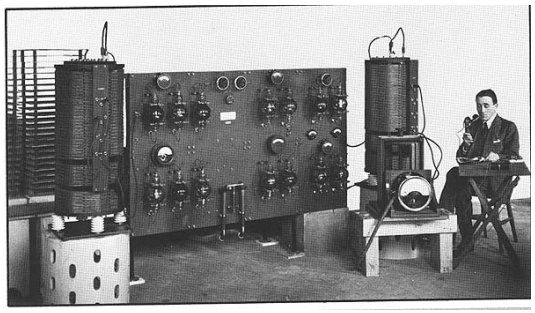
- Silicon Carbide (SiC) transistors
  - High temperature (operate 600-1000°C)
  - Radiation hard (operate inside nuclear reactors) to survive space voyage exposure
  - Processed at 2000°C in manufacture
  - $F_T$ of 10 GHz (will work at S-band, 2 GHz)
  - We had just finished two years on a military project learning how to use them
  - Using commercial die by Cree Inc.

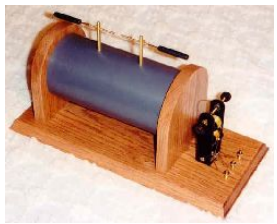
# The Solution

- "Olde Tyme Radio"
  (with apologies to Marconi…)
  - Obvious that no modern components will survive (much less work) at 465°C
    - We have the charred remains to prove it….
  - Only silver solder, welding or mechanical connections will survive (or NO connections)
  - We stepped back 100 years to find a survivable component solution

# The Solution

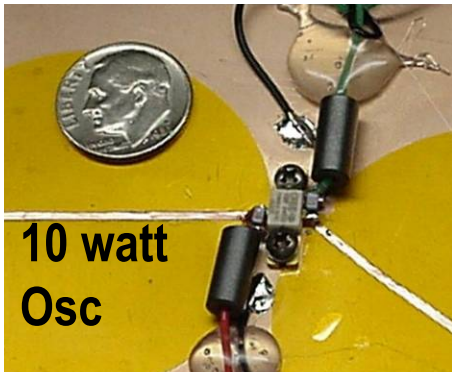
- "Olde Tyme Radio" *continues….*
  - All parts are metal selected, cut and bent for the desired electronic properties
  - No organics!
  - No solder!
  - (No wax, paper, wood, etc…)

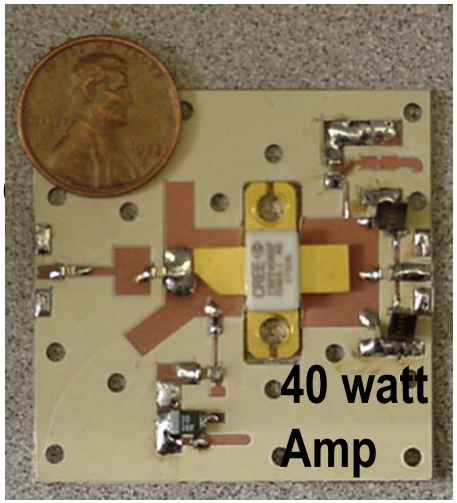




# Our Approach

- SiC transistors
- High temperature die attach/bonding
- Novel heatsinking
- Handmade metal/ceramic/glass comp
- Fewest possible parts
  - Oscillator (7), amplifier (6)
- Fewest possible connections
- Sealed but unpressurized case

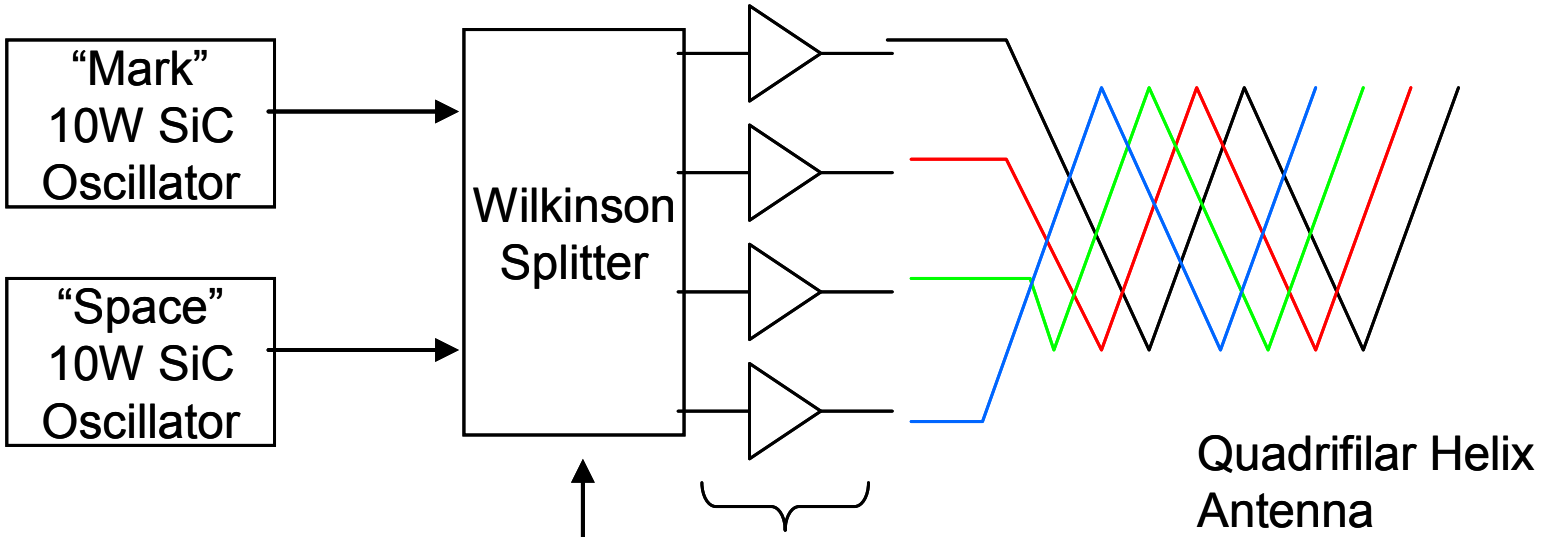


# Working Source List

- Brass
- Copper
- Steel
- Silicon Carbide
- Diamond
- Ceramic
- Glass
- Nichrome
- VHT engine paint
  - Ceramic, 1500°F, prior NASA spin-off
- Rutland Silicon Chimney Cement
  - 2500°F
- Silver solder
- Jeweler's welder
- Gold bonding
- Hi-temp die attach

# Preliminary System Architecture




Redundant Mark/Space FSK Oscillators Revert To OOK Mode on Failure of one Oscillator

# Testing the System

- Needed a low-budget means of simulating the Venusian environment
- Dr. Byrd suggested the "Ideal Gas Law":
  - Fill a sealed test chamber with the right $CO_2$ pressure at room ambient, heat to Venus temperature and produce Venus pressure
- Bought a used Autoclave Engineers small reaction chamber, outfitting with electrical penetrations for testing (ISGC)

# Summary

- Took on challenge of exterior ambient transmitter design for Venus (465°C)
- SiC transistors, hi-temp attach/bonding key
- Handmade olde-tyme metal components
- Minimize component, connection counts
- Redundant “fail-soft” architecture
- Novel low-cost test chamber
- Applicable to cold environments